The Holston uplift is reached at the summit between Wolf creek, North Branch, and the "rich valley" of Abraham's creek. There, one comes to the limestones of the Knox group, in contact with the highest rocks of the mountain limestone group, and two miles further along the railroad line the cherty beds of the Knox group are exposed. These are shown very near to Walker's mountain at a cross-road, where the soil is very ferruginous. The limestones of the overlying group are shown at but a little way from the gap by which the railroad passes through Walker's mountain.

A well-marked fault was crossed just behind Walker's mountain at somewhat more than four miles from Bristol, where the pyritous calcareous sandstones of the Knox group are shown in the gap through that ridge. The dip is abrupt at the head of the gap and increases to the mouth, where it becomes nearly 50 degrees, and the shaly layers are badly twisted. Exposures are very obscure between this locality and Bristol, where the line of section terminated; but the limestones of the Knox group are shown here and there, and the cherty beds of that group pass very near to Bristol.

Photodynamic Notes. By Pliny Earle Chase, LL.D.

(*Read before the American Philosophical Society, January* 21, 1881.)

1. *Chemical Synchronism.*

Maxwell* appears to have originated the theory, which is now generally accepted, of the equality of mean *vis viva* in the molecular movements of different gases, at equal temperatures. In 1863, I began to investigate some of the consequences of the theory, and the many evidences which I have adduced, of cyclical and harmonic vibrations in atmospheric and æthereal media,† have more than justified my belief of its importance.

All harmonies in elastic media necessarily involve some form of synchronism, and the progress of chemical physics may be helped by a knowledge of the general kinetic laws upon which such synchronism depends. If we designate velocity by v; density, by d; time of rotation, by t; modulus, by h; absolute temperature, by T; and the acceleration of a central force, by f, Maxwell's theory may be represented by the equation $v^2 d = k T$. In the fundamental equations of central force $v = \frac{f t}{2} = F \sqrt{fr}$; $h = \frac{ft^2}{4}$. When the efficient or fundamental velocity is constant, as in spatial Photodynamics, $f \propto \frac{1}{t} \propto \frac{1}{h} \propto \frac{h}{t^2} \propto \frac{1}{r}$; $t \propto h \propto \sqrt{\frac{h}{f}} \propto r \propto \frac{1}{f}$; $h \propto r \propto \frac{1}{f} \propto ft^2 \propto t$. Whenever we have occasion to consider derivative or second-

* P. Mag., 1860 [4], 19, 19.

† Proc. Amer. Phil. Soc., ix, 284-7; xvii, 109-12, 294-307; xviii, 224-32; xix, 4-9 20-5; *et al.*

ary velocities, the equations of variation, for any temporary constancy of f, t, h or r, can be readily found. In the investigation of spectral lines, chemical atomicities, and general kinetic phenomena, both cosmical and molecular, the consideration of f as a maximum often becomes especially important. Then it is evident that $f \propto \left(\frac{r^3 d}{r^2} = r\,d\right)$; $t \propto \sqrt{\frac{r}{f}} \propto \sqrt{\frac{1}{d}}$; the limiting time, therefore, becomes independent of distance, and is merely a function of density. In other words, *in a homogeneous medium, all analogous motions which are due to the accelerations of a central force, whether of rotation, vibration or translation, are synchronous.* In whatever way those motions may be affected by atomic, or molecular rotation, $v \propto r$, without any tendency to the production of internal disturbance. All cyclical harmonies and deformations must, therefore, be due to elasticity, or some other form of translatory interaction. In consequence of the proportionality of rotating velocity to the distance from the centre of rotation, it becomes possible to combine chemical elements of the most various densities; for, while there is perfect synchronism in the normal oscillations of each of the elements respectively, the atoms may intersect with radii which give them equal velocities of rotation at the locus of intersection, so as to produce secondary and subordinate synchronisms, such as are indicated by the harmonies of spectral lines, especially in Lockyer's "basic lines"* and in the lines of the widely diffused and important elements, Oxygen and Hydrogen.† As an illustration of the harmonies of independent and combined synchronism, we may take the three atoms, H_2O, condensed into two atoms of watery vapor. In rotation, induced, either directly or remotely, by the fundamental efficient velocity of light, we have seen that $t \propto \sqrt{\frac{1}{d}}$ and $v \propto \frac{r}{\sqrt{d}}$; therefore dv^2 is constant, in each of the elements, and in the compound, *e. g.*:

$$O\left(d = 16;\ v \propto \frac{r}{4}\right) + 2\,H\left(d = 1;\ v \propto r\right) = 2\,H_2O\left(d = 9;\ v \propto \frac{r}{3}\right)$$

and four oscillations of O are synchronous with one of H and three of H_2O.

Such varied evidences of synchronism, both *a priori* and *a posteriori*, may well encourage specialists, in all departments of physical science, to seek for harmonies, under the guidance of the "scientific use of the imagination." We may be assured that such harmonies are abundant everywhere, and we may also be assured that whatever harmonies we find are neither fortuitous nor lawless, although we may, in some cases, be unable to find any other reasons for their existence than the universal canon of nodal action. The more we study the detailed and coördinated ramifications of such action, the greater will be our appreciation and admiration of the order which is "heaven's first law," and the more confidently we can go on with our researches.

* Proc. Amer. Phil. Soc., xviii, 225–6.
† Ib., xix, 25.

2. *Magnetism.*

One of the fields in which there seems to be encouragement for much special investigation, is Electro-magnetism. I gave many reasons, sixteen years ago,* for regarding all magnetic phenomena as results of locally modified vibrations, and on that account I have always thought it to be somewhat illogical to speak of light as "an electro-magnetic phenomenon," thus subordinating the general to the special. According to the law of parsimony, the element of a common velocity indicates a common origin in radiant energy, but in denoting that energy it seems better to use a name which is universally recognized as appropriate, than one which may probably represent a mere local phenomenon. Among my reasons for adopting this opinion was the delay in the manifestations of solar influence. Father Secchi observed a remarkable solar outbreak on the 7th of July, 1872, which produced a great agitation of terrestrial magnetism, and Airy estimated the time required for the propagation of the magnetic disturbance at 2h. 20m. This is 16.87 times the time required for light to come from the Sun to the Earth, which is almost precisely the ratio between the time of terrestrial rotation and the time of satellite revolution at the Earth's surface.

More than seven years after I had shown that the solar daily variations of terrestrial magnetism might be very closely represented, both in form and magnitude, by solar tidal action, Maxwell suggested the same hypothesis.† I showed, in 1875,‡ that my hypothesis led to a simple estimate of Sun's mass, which I placed upon record, without, however, giving all the data for the calculation. The total terrestrial magnetic force in Great Britain has been found to be 10gr. ft. sec.; then the tension, perpendicular to the lines of force, is .128 gr. weight per sq. ft. The greatest magnetic tension which Joule was able to produce in Great Britain, by means of electro-magnets, was about 140 lbs. weight on the sq. in. ($= 140 \times 144 \times 7000 = 141120000$ gr. pr. sq. ft.). The unit of *vis viva*, in mechanical measure, varying as the square of the unit of velocity, is $m^2\ l^2\ t^{-4}$. But the molecular oscillation, in alternate approach to and recess from the orbital centre, continues for a half rotation or a half revolution, while the terrestrial antagonism lasts only $\frac{1}{\pi}$ as long. Therefore, if we designate Earth's mass by a subscript accent (m_1), the ratio of the magnetic force which is due to modified solar radiation, should bear the same ratio to the force of terrestrial reaction, as $m^2\ l^2\ t^{-4} : m_1^2\ l^2\ t^{-4}\ \pi^4$, or as $m^2 : m_1^2\ \pi^4$. This gives the proportion $m^2 : m_1^2\ \pi^4 :: 141120000 :: 128$, or $m : m_1 :: 327710 : 1$.

Although this result is nearly identical with the one deduced from the comparative leverage of Sun and Jupiter (327897), in the paraboloid of interstellar photodynamic action, I am inclined to think that it may be about one per cent. too small. When the difficulty of making precise magnetic

* Ib. Vol. ix, etc.

† Treatise on Electricity and Magnetism, ii, 127.

‡ Proc. Amer. Phil. Soc., xiv, 607–9.

measurements is considered, so slight a difference as this is hardly worthy of notice.

The experiments, which I performed before the Society in 1864 and 1865,* appear to have furnished the first direct and positive evidence of the hypothesis that electricity and magnetism consist simply of æthereal vibrations, which can be imitated and modified by simple mechanical means. This mechanical modification led, subsequently, to the invention of the telephone and the photophone.

3. *Earth's Orbital Eccentricity and its Correlations.*

The photodynamic importance of the centres of nucleation, condensation and nebulosity (Sun, Earth and Jupiter), in the solar system, and the tendencies to secondary and subordinate synchronisms, are further shown in moduli of rotation and in orbital eccentricities. The modulus velocity $\left(\frac{gt}{2}\right)$ of Jupiter is slightly greater, while that of Earth is slightly less, than Sun's wave velocity $(\sqrt{g_0 r_0})$; the slight differences being due, apparently, to the same causes as Earth's apsidal oscillations and its mean deviation from the centre of the belt of greatest condensation. Jupiter's secular range, from secular perihelion to secular aphelion ($.63295\rho_3$), is nearly the same as Earth's orbital radius of spherical gyration ($\sqrt{.4} = .63245\rho_3$); Jupiter's ratio of minimum eccentricity (.02549) is about three-quarters of Earth's ratio of mean eccentricity ($\frac{3}{4}$ of .03387 = .02540); at Jupiter's secular perihelion, or locus of rupturing oscillation, the projections of Sun's and Jupiter's centres from Sun's surface ($.93917 \times 5.2028 \times 214.55 = 1 + 1047.37$) are inversely proportional to their respective masses. We may, therefore, not unreasonably expect to find similar simple relations between different forms of terrestrial eccentricity and cosmical *vis viva.*

If we suppose the air to be condensed to the homogeneous density which is indicated by the theoretical velocity of sound, we may assign .4 of its velocity of equatorial rotation to the mean *vis viva* of simple spherical rotation, and the remaining .6 to æthereal or elastic action. The velocity of rotation is $2\pi \times 3962.8 \times 5280 \div 86164 = 1525.77$ ft.; the theoretical velocity of sound, $\sqrt{gh}$, should, therefore, be $.6 \times 1525.77 = 915.46$, and the height of homogeneous atmosphere $915.46^2 \div (32.088 \times 5280) = 4.9466$ miles.

This closeness of accordance with the values which have been derived from observation, accounts only for the equilibrium between the elastic and gravitating actions of daily rotation. The atmospheric particles, in their undulatory motion with the velocity of sound, may be regarded as traversing orbits with a mean eccentricity of $\frac{h}{r} = \frac{4.9466}{3962.8} = .0012483$. This result has been obtained by regarding the atmosphere as homogeneous, in the same way as our photodynamic results were obtained by regarding Sun's

* Ib., ix, 359; x, 151–66.

æthereal or luminiferous atmosphere as homogeneous. Therefore, if we consider Earth's mean orbital eccentricity as due to the elastic reaction of the nebular centre of oscillation (Jupiter) against the nucleal centre (Sun), we find :

Earth's mean atmospheric ecc'y : Earth's mean orbital ecc'y :: (Earth's semi-axis major)^2 : (Jupiter's semi axis major)^2; which gives .0012483 : .0033789 :: 1 : 5.2028^2. In order to acquire the velocity due to this eccentricity, there should be a fall of the centre of condensation (Earth) from the centre of the dense belt of planets, through one-half the height, or .016895 Earth's semi-axis major. In order to make the efficient wave producing *vis viva* at Earth equivalent to that at Sun's surface, we should take account both of Earth's (1.) and Jupiter's (.033789) action, as is done in the equation $1.033789 \frac{gt}{2} = \sqrt{g_0 r_0}$. Substituting $g = 32.088 \div 5280$, and $t = 86164$ sec., this gives 270.67 miles $= \sqrt{g_0 r_0}$. From this velocity we can readily deduce Earth's orbital velocity, which, being multiplied by the number of seconds in a sidereal year and divided by 2π, gives $270.67 \div \sqrt{214.55} \times 31558150 \div 2\pi = 92812000$ miles, for Earth's semi-axis major. The closeness of agreement between these photodynamic results and other estimated values is shown in the following table :

	Photodynamic.	Calculated from observation.		Difference.
Jupiter's secular range,	$.63245\rho_3$	Stockwell,	$.63295\rho_3$	.08 of 1 pr.ct.
" minimum ecc'y,	.02540	"	.02549	.36 "
Mass, Sun ÷ Jupiter,	1047.37	Bessel,	1047.88	.04 "
Theoretical vel. of sound,	915.46	Enc. Met.	916.322	.09 "
Homogeneous atmosphere,	4.9466	Silliman,	4.9478	.03 "
Earth's mean ecc'y,	.033789	Stockwell,	.0338676	.23 "
" " orbital fall,	.016895	"	.0169394	.26 "
" semi-axis major,	92812000	Cornu,	92803000	.01 "

4. *Cosmical and Molecular Densities and Velocities.*

We have seen that the function $t \propto \sqrt{\frac{r}{f}}$ is independent of any other element than d, when f is a maximum, or when comparisons are made at distances from the centre of force which are proportionate to their respective nucleal or atmospheric diameters. This renders the proportionality $t \propto \sqrt{\frac{1}{d}}$ an important one. For example, it is safe to predict that if the time of rotation of any single star should ever be discovered, it will be found to be such that $\frac{gt}{2}$ will not differ perceptibly from the velocity of light ; and from the times of rotation we can readily calculate the ratios of stellar to solar density. In binary and multiple stars, or in planetary systems where the planetary reactions are so important as either to retard or accelerate the rotary velocity of the nucleal mass, the value of the modulus velocity must still be some function of the velocity of light, although it may be so changed as to leave room for much interesting and perplexing study in seeking the causes and amounts of perturbation. In considering the equality of molecular *vis viva*, many well known evidences of atomic and molecular rotation have been found, but I know of none which furnish the necessary data for determining in what way the intrinsic rotations, which are due to simple reaction against the undulations of the luminiferous æther, have been modified by the accelerations of terrestrial rotation and the various unknown mechanical influences of chemical physics. The molecular velocity $v \propto \sqrt{\frac{1}{d}}$ accounts for all synchronisms of homogeneous media, but how are we to explain the synchronisms of rotation and revolution in a body so heterogeneous, and, consequently, with such various moments of inertia, as the Earth? If density itself was originally a function of distance fallen through, and, therefore, varied as t^2, the synchronous time for the aggregate of mean motions varied as $\sqrt{d}$. The equation $s = vt$ is, therefore, constant for any given radius. In order that this constancy may prevail, there must be some unit of density to represent either the modified æther, or some gas which is directly subjected to the influence of its vibrations. The hyper-elasticity of hydrogen, its wide diffusion, its continual presence in the solar explosions, the fact that it has the greatest tenuity of any substance which we have been able to measure with precision, its importance in relation to Lockyer's "basic lines," together with the simple and significant harmonic indications of those lines,* all point to it as the probable typical representative, or the transmitter, of primordial undulation. In order to test this hypothesis, let x represent the specific gravity or d of Earth; 270.67 m., the value of $\sqrt{g_0 r_0}$ at Sun, or Earth's modulus velocity of rotation; 6050, the molecular velocity of hydrogen; .0693, the ratio of the specific gravity of hydrogen to that of air; 773, the ratio of the specific gravity of water to that of air; $x \div 1.033789^3$, the mean specific gravity of Earth if expanded to $1.033789 \times$ its present radius, so as to eliminate the condensation due to the action of Jupiter. Introducing these values, in the constant equation $s = vt$, and considering v as the velocity acquired in t, the time of condensation, we have $\frac{270.67 \times 5280}{6050} = \sqrt{\frac{773\,x}{.0693 \times 1.033789^3}}$, and $x = 5.527$. The mean molecular velocity of earth which is due to æthereal elasticity, would then be $6050 \div \sqrt{\frac{773 \times 5.527}{.0693}} = 24.367$ ft. pr. sec.; the corresponding velocity of any terrestrial substance $= \frac{24.367 \times \sqrt{5.527}}{\sqrt{d}} = \frac{57.284}{\sqrt{d}}$ ft., if the density is compared with that of water, or $\frac{57.284 \times \sqrt{773}}{\sqrt{d}} = \frac{1592.655}{\sqrt{d}}$ ft., if air at 0° and 760 mm. is taken as the unit of density. These ratios are important in investigations which involve the modified or specific elasticity of bodies.

* Proc. Amer. Phil. Soc., xviii, 224–6.

5. *Photodynamic Estimate of Earth's Mass.*

I have shown, in my discussion of "Earth's orbital eccentricity and its correlations" (Note 3), that Sun's surface is the fulcrum of equilibrium between the two principal masses of our system (Sun and Jupiter), at the locus of rupturing projection, or the secular perihelion centre of gravity of Sun and Jupiter. I also showed, in my first paper on photodynamics, that the antagonistic mean leverage of Sun and Jupiter produces disturbances, at the directrix-locus of the stellar solar paraboloids, which furnish a very close approximation to the ratio between solar and terrestrial superficial gravitating energy. The forces which have established these harmonies must act under special conditions of equilibrium at the centre of condensation (Earth), and it seems probable that those conditions may be less subject to extraneous disturbance than either of the other adjustments which I have investigated.

In the photodynamic paraboloids, at any given instant, let a be the solar locus of the directrix which is on the side of Sun's centre opposite to Earth ; s_0, the centre of nucleation, or Sun's centre, regarded as a primary point of suspension for a linear pendulum ; s_3, the centre of condensation, or Earth's centre, the secondary point of suspension of the same pendulum; o_0, the centre of a primitive nucleal radius and also the centre of linear oscillation for s_3 ; o_3, the centre of linear oscillation for s_0 and also the common locus for coördinate radii r_0 and r_3 ; o_1, the centre of the linear pendulum $s_0\ s_3$; o_2 the centre of $s_0\ o_0$ and the centre of linear oscillation of $o_1\ s_0$; $r_0 = s_0\ o_3$; $r_3 = s_3\ o_3$; m_0, m_3, homogeneous masses varying as r_0^3, r_3^3 ; o_3 is the locus, in suspension from s_0, of opposite tendencies towards s_3 and s_0. Then $r_0 = 2r_3$; $m_0 = 8m_3$; if we represent the superficial momentum of any equatorial particle of m_3 by 1×1, the corresponding momentum for m_0, with reference to the same point of suspension (s_3) is 8×3. If the photodynamic momentum is converted into velocity of contiguous particles, at o_3, causing one of the particles to revolve about s_3, and the other, by reaction from s_0, about s_0, their respective velocities will be represented by $\sqrt{g_3 r_3}$ and $\sqrt{g_0 r_0}$, the latter being $(8 \times 3 = 24)$ times the former. Now $\sqrt{gr} \propto \sqrt{\frac{1}{r}}$ while $g \propto \frac{1}{r^2} \propto (\sqrt{gr})^4$. Therefore $g_0 = 24^4\, g_3$. But $g \propto m$, in mutual action and reaction, as in the case of Earth revolving and Sun rotating under the photodynamic influence of $gt = v_\lambda$; therefore $m_0 = (24^4 = 331776)\ m_3$. Radius varying as $\left(\frac{m}{d}\right)^{\frac{1}{3}}$, Sun's radius, r_0 should then be $(331776 \div .25527)^{\frac{1}{3}} = 109.07 r_3$; and Sun's mean distance, $\rho_3 = 214.5516 \times 109.07 \times 3962.8 = 92734000$ miles.

6. *Photodynamic Limitation of Terrestrial Day.*

The number and variety of the foregoing harmonies led me to look for some photodynamic influence on terrestrial rotation, or at the centre of density, analogous to that which is indicated by the solar nucleal equation, at the centre of nucleation, $\frac{gt}{2}$ = velocity of light. The acceleration of sun spots near the solar equator indicates a velocity which is partly rotational and partly orbital. The solar corona is now generally attributed to nebulous or meteoric matter, which is constantly tending either to fall into or to revolve about the Sun. If Sun's surface is the locus of the mean orbital collisions, the mean nebulous radius is $\frac{3}{2}r_0$, and the mean locus of the nebulous particles, r_a, is $\sqrt{\frac{3}{2}}r_0$. Let t_a be the time of half-rotation for r_a. in the fundamental equation $g_a t_a = v_\lambda$; then $t_a = \sqrt{365.2565} =$ 19.11168 dy, is a mean proportional between the solar terrestrial day and the terrestrial year. This gives for t_0, or the photodynamic modulus time at Sun's surface, $\frac{2}{3}t_a = 12.741123$ dy. Let n = the number of solar radii (r_0) in Earth's semi-axis major (ρ_3), and we have the equations:

$$v_\lambda = g_0 t_0 = 12.741123 \times 86400 g = n\, r_0 \div 497.827$$

$$g_0 r_0 = \left(\frac{n^{\frac{3}{2}} \times 2\pi\, r_0}{31558150}\right)^2 = n^3 r_0^2 \div (5022636)^2. \quad \text{Hence}$$

$$n = 214.5516.$$

$$g_0 = .0000003915 r_0.$$

$$2\pi\sqrt{\frac{r_0}{g_0}} = 10041.8 \text{ sec.}$$

$$2\pi\sqrt{\frac{r_3}{g_3}} = 5073.6 \text{ sec.}$$

$$\frac{d_0}{d_3} = \left(\frac{5073.6}{10041.8}\right)^2 = \frac{1}{3.9174} = .25527.$$

$$r_0 = 92{,}812{,}000 \div 214.5116 = 432580 \text{ m.}$$

$$\frac{g_0}{g_3} = \frac{r_0 d_0}{r_3 d_3} = 27.8657.$$

$$\frac{m_0}{m_3} = \left(\frac{r_0}{r_3}\right)^3 \times \frac{d_0}{d_3} = 332{,}500.$$

Another evidence of the limitation of the time of rotation, at the centre of condensation, by photodynamic influences, is found in the accelerations which are due to condensation within the present limits of the solar system. The central actions and reactions of acceleration between Sun and Earth vary as their respective masses, because $g \propto \frac{m}{d^2}$ and d is the same. In condensing nebulæ, equality of *vis viva* requires that t (of rotation) $\propto r^2$. From this source, therefore, Earth has been accelerated $(30.034)^2$ times by its "subsidence" from Neptune's mean orbital distance. This acceleration provides only for synchronous solar and terrestrial rotation; there has, however, been a further acceleration of 366.2565, by the shortening of the solar year to the terrestrial day, and of $\sqrt[4]{1.0145}$ by the mean "subsidence" of Neptune from its secular aphelion, since $\sqrt{gr} \propto \sqrt[4]{g}$. The quotient of Sun's mass by Earth's mass which will account for all these accelerations, is therefore, $\sqrt[4]{1.0145} \times 366.2565 \times (30.034)^2 = 331567$, a value which differs by only $\frac{1}{16}$ of one per cent. from the one last obtained by purely *a priori* indications, and $\frac{1}{3}$ of one per cent. from the one which was deduced from coronal oscillations.

7. *Photodynamic Limitation of Jupiter's Day.*

The centre of nebulosity (Jupiter) presents equally conclusive evidence of photodynamic acceleration, if we pay proper regard to the difference between the expansive reaction of elasticity and the gravitating action of condensation, with its consequent limitation of elasticity. If we take the "centre of primitive annular condensation" (Neptune), at its rupturing locus (secular perihelion $= 29.5982\rho_3$), the photodynamic seat of rupturing action* is at $\frac{5}{9}$ of $29.5982\rho_3 = 16.4434\rho_3$; squaring and multiplying by Sun's mass (1047.879), we get 10467 for the number of rotations in an orbital revolution. Dividing Jupiter's year (4332.5848 dy) by 10467, we get 9h. 56m. 3.4s. for the length of Jupiter's day. Prof. Hall's recent estimate is 9h. 55m. 26.5s.

8. *Moon's Mass.*

In the third note of the present series, I have shown some of the relations of Earth's orbital eccentricity to Jupiter's locus of rupturing oscillation, the masses of Sun and Jupiter, Earth's fall from the centre of the belt of greatest condensation, and the height of Earth's homogeneous atmosphere. The atmospheric elasticity should evidently be in equilibrium, between the mutual inter-actions of Earth and Moon, in the same way as the æthereal elasticity is in equilibrium between solar and planetary actions and reactions. The atmospheric eccentricity being .0012483, the ratio between the lunar and terrestrial masses, in order to be in equilibrium with this eccentricity, should be $\pi^2 \times .0012483$, or Earth's mass should be 81.17 times Moon's mass. What slight modifications of this value may be required, in order to satisfy other conditions, must be left for further investigation.

9. *Earth's Semi-axis Major.*

If we take the photodynamic estimate of the centre of the belt of greatest condensation (1.016895; Note 3), the ratio of r_0 to r_3, as determined by the mean locus of solar and terrestrial action proportionate to mass, should be 1.016895 times $\frac{214.5516}{2} = 109.088$. If we adopt Stockwell's computation of the secular centre of the belt of greatest condensation ($1.016939\rho_3$), the ratio is 109.093. These estimates give, for Earth's semi-axis major, 92750000 and 92754000 miles respectively.

* Proc. Amer. Phil. Soc., xii, 392-4; P. Mag., June, 1877, p. 353.

10. *The Photodynamic Year.*

The constant action of the constant photic energy, at the centre of solar and terrestrial action proportionate to mass, is equally divided between Earth and Sun, so that $g_3 t_3$ for Earth corresponds with $\frac{g_0 t_0}{2}$ for Sun, when so expanded that its rotation would be synchronous with the terrestrial year. We therefore find for the velocity of light, if we allow for the acceleration due to the photodynamic projection of Neptune (Note 6),

$$\frac{g \times 1 \text{ yr. in sec.}}{(\text{Neptune's projection})^2} = \frac{32.088 \times 31558150}{5280 \times 1.0145^2} = 186345 \text{ miles per sec.}$$

Multiplying by 497.827, the time required for light to come from the Sun, we get 92,767,260 miles for Earth's semi-axis major.

11. *Masses of Jupiter and Saturn.*

In consequence of the simplicity of Earth's relation to the centre of condensation, the *a priori* approximation to its mass is comparatively easy; but all the requirements of photodynamic *vis viva* must be satisfied in each of the cosmical masses, as well as in every chemical atom and molecule. Jupiter's synchronous radius, or the distance from Jupiter's centre ($.51231\rho_3$), at which a satellite would revolve in one of Jupiter's orbital revolutions, is 1.0246 × the radius of confluent solar and terrestrial mass action. The time of any circular orbital revolution is ($\sqrt{32} = 5.6568$) × the time of fall to the centre of force. The accelerations of gravity varying as the fourth power of orbital velocity, and acquired velocity varying as gravitating time, the mass, which would satisfy conditions of simple equilibrium between tendencies to condensation and to orbital motion, is $5.6568^4 = 32^2 = 1024$. Sun's mass : Jupiter's mass :: 1047.879 (= 1.0234 × 1024) : 1. This indicates a modification of the equilibrating mass, similar to the modification of the synchronous radius. The difference between 1.0234 and 1.0246 is less than one eighth of one per cent., which is within the limits of probable errors of observation. The rupturing photodynamic ratio ($\frac{5}{9}$; see Note 7), and the ratio of photodynamic projection (1.01455;* see Note 10), have both been introduced, as factors of equilibrium, between the centre of nebulosity (Jupiter) and the nebular centre of planetary inertia (Saturn);† for $(\frac{5}{9} \times 1.01455)^2 \times 1047.879 = 3501.6$ which is Bessel's estimate of the quotient of Sun's mass by Saturn. This deduction of Saturn's mass, therefore, indicates (Note 10) a velocity of light equivalent to $\frac{32.088 \times 31558150}{5280 \times 1.01455^2} = 186326$ miles, and gives, for Earth's semi-axis major, 92,758,000 miles.

12. *Photodynamic Centre of Planetary Inertia.*

Saturn's position, at the nebular or photodynamic centre of planetary inertia, furnishes special and very interesting crucial illustrations of the

* This value is about $\frac{1}{23\frac{1}{3}}$ of one per cent. greater than Stockwell's estimate of that of Neptune (1.0145066).

† Proc. Am. Phil. Soc., xviii, 431.

cosmical influence of harmonic nodes in an elastic medium. Let v_λ be the velocity of light; g_x, the acceleration of gravity at r_x, the radius of Sun's photodynamic sphere; $v_x = \sqrt{g_x r_x}$ = orbital velocity at r_x; v_0 = orbital velocity at r_0 (Sun's surface), and modulus velocity, $\left(\frac{gt}{2}\right)$, for centres of nebulosity and of condensation (Jupiter and Earth), the modulus velocity having been slightly changed, as we have seen, by forces which produce orbital eccentricity; $M_x = \frac{g_x t_x^2}{4}$; r_1, radius of orbital revolution synchronous with nucleal rotation; $\left(\frac{v_\lambda}{v_x}\right)^2 = \frac{M_x}{r_x} = \frac{g_x t_x^2}{4 r_x}$; $M \propto r_x^2 \propto r_1^{\frac{3}{2}}$; $r_1 \propto r_x^{\frac{4}{3}}$; $r_2 = \sqrt{r_x r_1} \propto r_x^{\frac{7}{6}} \propto r_1^{\frac{7}{8}} \propto M^{\frac{7}{12}}$; $r_2^{\frac{12}{7}} \propto M$; $r_2^{\frac{6}{7}} \propto M^{\frac{1}{2}} \propto \frac{1}{v_x} \propto \frac{1}{v_2} \times \left(\frac{r_x}{r_2}\right)^{\frac{1}{2}} \propto \sqrt{r_0}$. If we take r_0 as the unit of distance, we have, for the present condition of the solar system, $r_x = \sqrt{M r_0}$; $\left(\frac{r_2}{r_0}\right)^{\frac{6}{7}} = \sqrt{\frac{M}{r_0}} = \frac{v_\lambda}{v_2} \times \left(\frac{r_0}{r_2}\right)^{\frac{1}{2}}$; therefore $\left(\frac{r_2}{r_0}\right)^{\frac{19}{14}} = \frac{v_\lambda}{v_2} = \frac{t_2}{t_\lambda}$. But $\frac{t_2}{t_\lambda}$ = the time in which light would traverse Saturn's orbit, divided into the time of Saturn's orbital revolution; therefore $\left(\frac{r_2}{r_0}\right)^{\frac{19}{14}} = 9.5389^{\frac{3}{2}}$ years $\div$ ($9.5389 \times 2\pi \times 497.825$ seconds) $= 31160.4$; $\frac{r_2}{r_0} = (31160.4)^{\frac{14}{19}} = 2046.8$. This gives for Earth's semi axis major $\frac{2046.8 r_0}{9.5389} = 214.575 r_0$.

13. *Earth's Rupturing or Projectile Locus.*

In Note 6, I have shown the relation of Earth's accelerated rotation to Neptune's subsidence and Sun's mass. In Note 5, I deduced a value for Earth's mass from simple considerations of linear oscillation, between the nebular centre of the solar system and the centre of greatest condensation. Since the stability of the system requires that all its oscillations should be harmonic, we may also account for Earth's rotary acceleration by simple solar and terrestrial inter-actions. The propagation of rays of equal length, in an elastic medium, produces a terrestrial reaction to its orbital motion, through a radius equal to Sun's radius. The centre of linear oscillation, in terrestrial revolution, which limits the tendencies of photodynamic *vis viva* towards the earth, is at only $\frac{1}{3}\rho_3$ from Earth, or near Venus's secular perihelion; the pendulum of solar action upon Earth (ρ_3) is three times as great. The sum of the masses of Earth and Sun being involved in these actions and reactions, there is a consequent acceleration which would give the Earth nine rotations per annum from this source alone. This acceleration is further increased by the relations of orbital velocity, due to Sun's mass acting through Earth's secular perihelion or projectile radius vector, which may be represented by $\sqrt{\frac{m_0}{\rho_3}}$, and to Earth's mass acting through a radius equal to Sun's semi-diameter, which may be represented by $\sqrt{\frac{m_3}{r_0}}$. Therefore we have the proportion $\sqrt{\frac{m_0}{\rho_3}} : \sqrt{\frac{m_3}{r_0}} :: 366.2565 : 9$. Hence $\frac{m_0}{m_3} = \left(\frac{366.2565}{9}\right)^2 \times \frac{\rho_3}{r_0}$. Introducing Stockwell's ratio for Earth's projectile radius vector (.9322648) we find $\frac{\rho_3}{r_0} = .9322648 \times 214.5516 = 200.02$, and $\frac{m_0}{m_3} = 331252$.

14. *Callisto, Jupiter's Telluric Moon.*

The combined influence of harmonic photodynamic oscillations on the three important centres, of nucleation (Sun), condensation (Earth), and nebulosity (Jupiter), is further shown by the proportion:

Jupiter's isochronous radius : Callisto's semi-axis major :: $\sqrt{\frac{m_0}{\rho_3}} \quad \sqrt{\frac{m_3}{r_0}}$ :: 366.2565 : 9. Searle* gives for the distance and period of Callisto, $.012585\rho_3$ and 16.689 days. This would make Jupiter's isochronous radius $.012585\rho_3 \times (4332.5848 \div 16.689)^{\frac{2}{3}} = \frac{366.2577}{9} \times$ Callisto's semi axis major $= .51231\rho_3$. The value thus obtained for Earth's sidereal year differs from the observed value by only $\frac{1}{3000}$ of one per cent. Other harmonic influences, analogous to those which we have already considered, are traceable in the following equations: 1. $\left(\frac{2}{3}\right)^4 \times$ Jupiter's mean aphelion projection $\times$ Earth's day $=$ Jupiter's modulus time, or time of half rotation. This gives, for Jupiter's day, 9h. 53m. 26.5s. 2. $\frac{2}{3} \times \frac{\text{Jupiter's semi-axis major}}{\text{Earth's semi-axis major}} \times$ time of revolution at Jupiter's surface $=$ 9h. 54m. 11.6s. 3. $2^4 \times 1.04316 \times$ Jupiter's semi-diameter $= 16.69056r =$ Callisto's semi-axis major. 4. $3^3 \times$ Earth's day $=$ Callisto's orbital time (26.9984 dy). 5. Jupiter's modulus velocity $\div$ Earth's ratio of aphelion projection (1.0677352) $=$ 271.23 miles. This gives 186830m. for the velocity of light, and 93010000m. for Earth's semi-axis major.

15. *Probable Values.*

I subjoin, for comparison, a few of the results of the foregoing methods of questioning nature, under the simple guidance of the well-known law that every action *must have* an equal and opposite reaction. The dates refer to publication in the Proceedings of the American Philosophical Society.

Flame energy,	Feb. 16, 1872,	92639500
Basic lines,	April 4, 1879,	93203000

* Outlines of Astronomy, Sect. 795.

Earth's orbital unit,	April 4, 1879,	92579000
Cosmical masses,	" "	92549000
Neptune's radius vector,	" "	92717000
Primitive condensation,	Jan. 4, 1880,	92520000
Sun and Jupiter,	" "	92606000
Nodal action,	March 19, 1880,	92711850
Hydrogen,	April 16, "	92756000
Oxygen,	" "	92849000
Undulatory *vis viva*,	Note 3,	92812000
Earth's mass,	" 5,	92734000
Terrestrial day,	" 6,	92714000
Earth's semi-axis major,	" 9,	92752000
Earth's year,	" 10,	92767260
Jupiter and Saturn,	" 11,	92758000
Earth's projection,	" 13,	92590000
Jupiter's day,	" 14,	93010000

These combined results indicate a value, for Earth's semi-axis major, of 92737100m. $\pm$ 25700; the probable error being less than $\frac{1}{36}$ of one per cent. This gives, for the velocity of light, 299854 $\pm$ 83 kilometres. In the *American Journal of Science*, for January, 1880, pp. 59–64, D. P. Todd discusses Foucault's, Cornu's and Michelson's experimental estimates of the velocity of light. The following table gives his several values, together with Michelson's final estimate (III), and my own:

Foucault	298000 km.
Cornu, I	298500 "
" II	299990 "
Michelson, I	300100 "
" II	299930 "
" III	299820 "
Todd	299920 "
Chase	299854 "

Stated Meeting, February 4, 1881.

Present, 9 members.

Vice-President, Mr. Eli K. Price, in the Chair.

Letters accepting membership were read from Dr. Chas. Stewart Wurts, 1701 Walnut St., Jan. 24, 1881; Mr. Henry Carvill Lewis, Germantown, Jan. 25, 1881; Capt. E. Y. McCauley, Lima, Delaware Co., Pa., Jan. 26, 1881; Mr. Addison May, West Chester, Pa., Jan. 26, 1881; and Prof. Joseph Lovering, Cambridge, Mass., Jan. 31, 1881.